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Ungulate Census of North Shore And Adjacent Areas, Peace Arm, Williston Reservoir, March 1989

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SUMMARY

A stratified block helicopter-based census of two contiguous areas north of the Peace arm, Williston Reservoir was undertaken in mid-March 1989. Total moose populations were estimated at 671 and 1256 west and east of Butler Ridge respectively. Elk, sheep and caribou were observed west of Butler Ridge only and were estimated to number 189, 99 and 265 respectively. Moose were widely distributed throughout the areas, with lowest densities in the Schooler Creek drainage. Elk were limited to the ridges overlooking Williston Reservoir, while caribou and sheep were limited in distribution to the highest ridges surrounding the local watersheds. Areas suitable for future habitat enhancement by burning and/or cutting were identified.

1. INTRODUCTION

A helicopter-based census of two areas north of the Peace arm of Williston reservoir, northern B.C., was undertaken in mid- March 1989. The census was intended as a baseline inventory of the area prior to habitat management and enhancement required by the Williston Reservoir compensation program.

2. METHODS

2.1 Census Areas

The survey area consisted of two contiguous blocks, termed Areas 1 and 2 respectively, situated north of, and adjacent to, the Peace arm of Williston Reservoir (Figure 1). Area 1 is a steeply dissected 846 km2 area containing the watersheds of four Peace arm tributary creeks - Schooler, Adams, Aylard and Dunlevy. Elevations range from 670 m at the reservoir shoreline to over 1760 m along the bordering ridgelines. Forest cover consists of boreal spruce at lower elevations, intergrading with montane spruce types at higher elevations. The ridgelines surrounding and penetrating the area support typical alpine tundra which is bordered by krumholz and sparsely wooded cover. Forest cover in many portions of Area 1 has been modified by periodic burns and is in various successional stages, including dense deciduous and coniferous types. The south-facing ridges overlooking the reservoir support a mosaic of cover types, ranging from dense spruce forest to open aspen stands and low brush. Areas 1 and 2 are separated by Butler Ridge, a 1700 m north-west trending ridgeline capped by tundra. Area 2 is a low relief 522 km2 area of boreal spruce forest admixed with dense aspen and poplar stands. About 15 percent of Area 2 is under cultivation.

2.2 Stratification of Census Areas

The census technique used was a stratified random block design, using a helicopter as the observational platform. Previous use of similar census technique in dense boreal forest in northern B.C. (Goulet and Haddow 1985) indicated several important criteria for sampling design, including the desirability of a pre-sampling or pilot survey to determine sampling strata, and the need to be able to rapidly identify sample plot boundaries from the air.

Stereoscopic examination of recent (1986) 1:60,000 air photos indicated some features of basic importance to sampling design.

a. Area 1 is very heterogeneous in terms of terrain features and vegetative cover; sample plots had to be restricted in size if they were to be relatively homogeneous.

b. Large areas of Area 1 are covered by dense canopied spruce forest with limited aerial visibility for solitary species such as moose.

A pre-census stratification survey using fixed wing aircraft (Goulet and Haddow 1985, Gasaway et al. 1986) was considered but rejected since it was considered that the efficiency of fixed wing censuses in the steeply dissected, heavily forested terrain would be inadequate for planning sampling design. A pre-census helicopter survey of the area would have been more effective but was ruled out because of cost considerations. Pre-survey typing of the areas from air photos plus reference to wildlife biophysical mapping in the McGregor Plateau area south of Williston Reservoir (Ministry of Environment 1982) suggested a number of potential sampling strata based on terrain, elevation, vegetative features and land use which would maximize differences in ungulate density.

Area 1 was divided into four strata - coniferous forest, serai forest, south slopes, and ridges. Coniferous forest consisted of all mature spruce forest plus the older burns. Serai forest comprised all deciduous forest cover, mixed coniferous-deciduous cover, recent burns and clear-cut areas. South slopes included a variety of types which were subject to southern, south-eastern or south-western exposure and which had relatively sparse tree density and canopy cover. Ridges consisted of higher elevation tundra areas. Creek bottoms were identified as a possible sampling stratum from air photo interpretation, but were abandoned during the actual survey because of their very limited surface area and the lack of precision in measuring the actual areas censused. Any moose observed in creek bottoms were allocated to the stratum traversed by the creek - usually coniferous or serai forest. Area 2 was mapped into three strata - coniferous forest, serai forest (chiefly aspen and poplar stands) and agricultural lands.

Each stratum was divided into sample census plots on the basis of easily identifiable topographic landmarks such as creeks, ridgelines, roads, cut lines, etc. The initial objective was to delineate all strata into plots

of 1-2 km2 in area, following Goulet and Haddow (1985). Smaller plots had to be delineated in most parts of Area 1 because of the nature of the terrain. Plots in Area 2 were closer to the 1- 2 km2 objective. All plots were numbered sequentially within strata and their positions marked on transparent air photo overlays. The lists of plot numbers within each stratum were scrambled by computer to produce modified lists from which randomly selected plots could be taken in ordered sequence.

An adaptive sampling program was followed to maximize sampling efficiency and ensure that samples were taken in proportion to ungulate densities. Plots were selected per stratum in proportion to the respective ungulate sample variance. No estimates of sample variances were available prior to the census so proportions were used which were arbitrarily assumed to indicate the relative use of the strata by all of the three principle ungulate species - moose, elk and sheep. Two-thirds of the overall sampling effort was allocated to Area 1 because of its higher priority in the wildlife compensation program. Estimates were made of the time required to census plots within various portions of the survey areas (based on the experience of Goulet and Haddow 1985), and a provisional total number of plots was estimated. These were apportioned amongst the strata according to the proportions noted above. The required number of plots per stratum were read off the random selection lists and marked on the air photos. Areas of sample plots were measured on the air photos by planimeter. The scale of the air photos was corrected by reference to the 1:50,000 NTS maps of the area (1:60,000 air photos were found to have a mean scale of 1:67,700).

Following each day's censusing the apportioning of sample plots amongst strata was recalculated based on a relative variation factor (RVF) for each stratum. RVF's were computed (Gasaway et al. 1986) as

$$RVF = \frac{\text{Stratum area}}{\text{Mean sample unit area}} \times \sqrt{\text{Stratum variance}}$$

Additional plots were added to strata with high RVF's and plots not yet censused were deleted from the lists for strata with lower RVF's to adjust the total number of plots sampled per stratum. RVF's are based on the computation of a variance for each stratum which assumes a normal distribution. Survey data were subsequently found not to be normally distributed (see Appendix B), however the technique was still considered valid

since it directed sampling effort towards strata with higher variations and therefore higher densities of ungulates. Square root transformations of ungulate number per plot were used in RVF compilation to improve the normality of the distributions.

Following the census, a grid based on UTM coordinates was overlaid on the aerial photographs and sample plots were grouped within 25 km^2 quadrants. Census data were compiled in two groups, i.e. according to plots within strata, and according to quadrants regardless of strata. The larger quadrants were used for the computation of confidence limits for total moose estimates (see Appendix B).

2.3 Census Technique

The census was conducted over a 3-day period in mid-March 1989 using a Bell 206 helicopter based in Hudson Hope. The census crew comprised, in addition to the pilot, a navigator- observer and one or two observers. Dunlevy Creek watershed was selected as the initial sampling area since it contained the best mix of sampling strata and provided a large enough sample after one day's censusing to permit computation of plot means and variances. Air photos were carried in the helicopter and used as navigational aids to find the boundaries of the sample plots. The perimeter of each plot was flown first, followed by concentric strips towards the centre. The width of each strip was subjectively gauged to permit complete coverage of the plot. Air speed during searches was 40-60 knots. Moose, elk, sheep and caribou were classified into age and sex categories. Numbers and locations only of deer were recorded. Additional data collected for each plot included canopy density (5-point scale), track abundance (5-point scale) and snow cover and depth (4-point scale). Track abundance usually referred to moose tracks, except in alpine areas where caribou were mainly responsible for track patterns. Snow depth was judged in relation to the dimensions of moose seen in the snow and hence was generally not estimated for zero count plots.

Repeat counts were made of plots when one of two conditions occurred - relatively high number of moose seen in a plot with high cover density, or else no moose seen in plots with abundant moose track. The objective was to obtain more efficient counts and thereby to estimate a correction factor for estimating moose densities. Regression of moose numbers per plot on track, canopy and snow cover indices was used as an additional method of estimating this correction factor (Appendix B).

3. SAMPLE CENSUS RESULTS

Excellent conditions prevailed during the census. Temperatures ranged from -2 to -30°C, with zero cloud cover and no wind. Fresh snow fell approximately 3-4 days prior to the census and fresh tracks could easily be identified.

Helicopter search time required was found to be less than estimated prior to the survey. The time required for finding and searching plots averaged 3.2 minutes per plot, while total helicopter usage, including commuting time, averaged 3.5 minutes per plot. Numbers of plots sampled per stratum were therefore increased to total 242 for Area 1 and 95 for Area 2. Total stratum coverage averaged 19.3 percent for Area 1 and 17.6 percent for Area 2 (Tables 1 and 2). Mean plot sizes were larger for Area 2 (0.97 km2) than for Area 1 (0.68 km2) because of the more homogeneous terrain.

Repeat counts of 15 plots resulted in an estimated correction factor of 8.5 percent for moose in Areas 1 and 2 (Appendix B). This could be considered a minimum average correction factor for all strata for both census areas. A more efficient correction factor was estimated for moose for each stratum within each area through the use of multiple regression coefficients to adjust observed moose numbers according to the prevailing track and canopy cover indices (Appendix B). These correction factors varied from 3.9 and 6.3 percent in strata with good visibility to 87.5 percent in dense coniferous forest. Correction factors were not estimated for other species (see Appendix B).

Census data were accumulated for four species - moose, elk, sheep and caribou and densities and overall population estimates were made for these species. Mule deer and white- tailed deer were occasionally observed and recorded but the data were regarded as inadequate for population estimates. Sheep and caribou were largely confined to the higher elevations along the Aylard, Adams and Schooler creek drainages. Approximately one-quarter of the ridge stratum along Butler Ridge was sampled and few caribou or sheep were sighted although recent tracks were noted in some plots.

Table 1. Aerial censusing summary data for Area 1.

	Stratum				
	Coniferous Forest	Seral Forest	South Slopes	Ridges	Totals
No. plots sampled	68	72	63	39	242
Mean plot size (km2) (Range)	0.70 (0.17-1.47)	0.78 (0.27-1.74)	0.67 (0.11-1.28)	0.45 (0.22-1.20)	0.68 (0.17-1.74
Total area sampled (km2)	47.6	56.2	42.2	17.6	163.5
Stratum area (km2)	449.1	201.9	129.3	65.7	
Stratum sample coverage (%)	10.6	27.8	32.6	26.7	19.3
No. observed moose	8	53	79	0	140
No. moose adjusted (*1) (Adjustment %)	15 (+87.5)	68 (+28.3)	84 (+6.3)	0	167 (+19.3)
No. observed elk	0	10	50	0	60
No. observed sheep	0	4	0	22	26
No. observed caribou	0	0	4	66	70

*1 numbers adjusted according to track density index, canopy cover index and sample plot size - see Appendix B

Table 2. Aerial censusing summary data for Area 2.

	Stratum			
	Coniferous Forest	Seral Forest	Agricultural Lands	Totals
No. plots sampled	30	47	18	95
Mean plot size (km2)	1.03	0.91	1.02	0.97
(Range)	(0.52-2.48)	(0.35-1.52)	(0.35-1.91)	(0.35-2.48
Total area sampled (km2)	30.9	42.8	18.4	92.0
Stratum area (km2)	235.9	206.9	79.0	521.8
Stratum sample coverage (%)	13.1	20.7	23.2	17.6
No. observed moose	59	88	51	198
No. moose adjusted (*1)	68	102	53	223
(Adjustment %)	(+15.3)	(+15.9)	(+3.9)	(+12.6)

*1 numbers adjusted according to track density index - see Appendix B

4. POPULATION DENSITIES

Two types of densities were estimated for the four principle species - an overall or "crude" density for each stratum, and a density based on occupied plots only (Tables 3 and 4). The latter parameter tends to be an estimate of mean group size for each species.

Overall moose densities were estimated at 1 per km2 in Area 1 and 2.2 km2 in Area 2. Moose numbers in the south slope plots in Area 1 (highest densities in Area 1) were highly statistically different to those in all strata in Area 2 (Kruskal-Wallis H = 27.8, $p<0.001$, Zar 1984). Moose numbers per plot in Area 2 were not statistically different from one another (Kruskal-Wallis H - 1.25, $p>0.50$). Total moose populations in Areas 1 and 2 were estimated at 671 and 1256 respectively.

Elk occurred only in Area 1, predominantly along the south slopes overlooking Williston Reservoir. Crude densities in this stratum were 1.2 per km2, but actual densities per plot were as high as 19.7 per km2 along the reservoir shoreline (Table 3). The elk population estimate for the south slope stratum in Area 1, based on sample plot densities, was 153 which was less than the actual number of elk seen in that stratum (=194, included elk seen outside sample plots). Sheep and caribou occurred predominantly on ridges in Area 1 and total populations were estimated at 99 and 265 respectively (Table 3).

A modified Poisson distribution was used to fit the data and obtain an estimate of the confidence limits to means within strata (Appendix B). The disadvantage of the Poisson distribution is that confidence limits are estimated on the basis of a chi-square distribution (Zar 1984) and thus tend to be wide (especially lower confidence limits) when mean densities are low. Quadrant data (25 km^2) were used to compute population confidence limits for moose (Tables 3 and 4) since these data were approximately normally distributed. They were found not to provide any advantage in the case of the other species, however, and the Poisson-based confidence limits were used (Table 3).

Table 3. Ungulate density and population estimates for Area 1.

		Stratum			
		Coniferous Forest	Seral Forest	South Slopes	Ridges
Moose	mean density in all plots (#/km2)	0.3	1.2	2.0	0.0
	proportion of sample plots occupied (*1)	0.15	0.61	0.32	0.0
	mean density in occupied plots (#/km2) (*1)	2.3	2.0	6.5	0.0
	population estimate per stratum (90% confidence limits) (*4)	153 (17-533)	248 (68 - 874) (*2j	270 (103-608)	0
	overall population estimate (90 % confidence limits) (*2)	<——— 671 ——— (522-1066)			——>

Continued >

Table 3. Continued.

		Stratum			
		Coniferous Forest	Seral Forest	South Slopes	Ridges
Elk	mean density in all plots (#/km2)	0.0	0.2	1.2	0.0
	proportion of sample plots occupied (*1)	0.00	0.05	0.06	0.00
	mean density in occupied plots (#/km2) (*1)	0.0	36	19.7	0.0
	population estimate per stratum (90% confidence limits) (*4)	0	36 (10-78) (*3)	194 (89 - 239X*3)	0
	overall population estimate (90 % confidence limits) (*4)	<-- 230 (207 - 307) -->			

Continued -->

Table 3. Continued.

		Stratum			
		Coniferous Forest	Seral Forest	South Slopes	Ridges
Sheep	mean density in all plots (#/km2)	0.0	0.1	0.0	1.3
	proportion of sample plots occupied (*1)	0.00	0.01	0.00	0.14
	mean density in occupied plots (#/km2) (*1)	0.0	7.2	0.0	9.2
	population estimate per stratum (90% confidence limits) (*4)	0	15 (6 - 29)	0	84 (28 - 187)
	overall population estimate (90 % confidence limits) (*4)	<——— 99 ——— (67 - 216) ———>			

Continued -->

Table 3. Continued.

		Stratum			
		Coniferous Forest	Seral Forest	South Slopes	Ridges
Caribou	mean density in all plots (#/km2)	0.0	0.0	. O . 1	3.8
	proportion of sample plots occupied (*1)	0.00	0.00	0.05	0.16
	mean density in occupied plots (#/km2) (*1)	0.0	0.0	1.9	24.1
	population estimate per stratum (90% confidence limits) (*4)	O	O	12 (4-31) (*3)	253 (135 - 425)
	overall population estimate (90 % confidence limits) (*4)	< 265 (145 - 485) >			

1 estimated by fitting data to Poisson distribution - see Appendix B
2 estimated from normally distributed quadrant data - see Appendix B
3 lower confidence limit is estimated by actual number counted.
4 estimated from Poisson distibuted plot data - see Appendix B

Table 4. Moose density and population estimates for Area 2.

		Stratum		
		Coniferous Forest	Seral Forest	Agriculture Lands
Moose	mean density in all plots (#/km2)	2.2	2.4	2.9
	proportion of sample plots occupied (*1)	0.59	0.75	0.63
	mean density in occupied plots (#/km2) (*1)	3.5	3.3	5.2
	population estimate per stratum (90% confidence limits) (*2)	482 (146 - 1143)	515 (139 - 1322)	259 (96 - 513)
	overall Deputation estimate (90 % confidence limits (*3)	< 1256 (709 - 1754) >		

* 1 estimated by fitting data to Poisson distribution - see Appendix B
* 2 estimated from Poisson distributed plot data - see Appendix B
* 3 estimated from normally distributed quadrant data - see Appendix B

5. POPULATION DISTRIBUTION

Population distributions estimated on the basis of sightings (Figures 2 to 5) indicated significant heterogeneity for all four species considered. Moose were fairly evenly distributed across Area 2 (Figure 2); this was confirmed by the similar densities in all strata in Area 2 (Table 4). The general scarcity of moose in the Schooler Creek drainage in Area 1 (Figure 1) appears to be related to the generally steeper and higher elevation terrain in that area, plus the higher proportion of mature coniferous forest cover which supports overall moose densities from 2 to 7 times lower than other strata. Moose are evenly distributed across the western portion of Area 1, being only restricted by the higher elevations on Butler Ridge.

Elk were found to be limited to exposed south-facing slopes at lower elevations (generally below 1000 m) along the reservoir shoreline (Figure 3). South-facing slopes in Area 1 away from the shoreline were not utilized by elk which suggests the presence of an influence related to the proximity of the reservoir.

6. AGE AND SEX RATIOS

No statistical differences between age and sex ratios of moose in different strata or between moose in and outside of sample plots in Area 1 were found (chi-square tests, $p>0.25$ in all cases). The grouped ratios (Tables 5 and 6) can thus be used for the moose populations in Area 1. There was a significantly higher proportion of bulls in seral forest in Area 2 (chi-square = 6.62, 3 d.f., $0.05 < p < 0.10$), but no bulls were found in agricultural lands. Because of these skewed proportions there was a significantly higher proportion of bull moose in Area 1 than in Area 2 (chi-square = 6.9, 1 d.f., $p<0.001$). Higher hunting mortality in Area 2 because of easier access would appear to be one reason for this phenomenon. There is no significant difference between adult female:juvenile moose proportions in Areas 1 and 2 (chi-square = 1.33, 1 d.f., $0.10 < p < 0.25$), suggesting comparable reproduction and juvenile mortality rates in the two areas.

Age and sex counts for elk, sheep and caribou were too sparse for some strata to permit statistical comparisons between strata. Overall ratios

Table 5. Area 1: age and sex classification of observed moose.

	Stratum					
	Coniferous Forest	Seral Forest	South Slopes	Ridges	Outside Sampled Plots	Totals
Adult males	3	12	17	0	2	34
Adult females	4	28	43	0	13	88
Adult unsexed	0	5	1	0	5	11
Juveniles	1	6	18	0	3	28
Unclassified	0	2	0	0	4	6
Sex ratios: adult females/male	1.33	2.33	2.53	-	-	2.59
Age ratios: juveniles/adult female	0.25	0.21	0.42	-	-	0.32
juveniles/adult	0.14	0.13	0.30	-	-	0.21

Table 6. Area 2: age and sex classification of observed moose.

	Stratum				
	Coniferous Forest	Seral Forest	Agricultural Lands	Outside Sampled Plots	Totals
Adult males	6	15	0	1	22
Adult females	36	51	37	6	130
Adult unsexed	4	5	0	5	14
Juveniles	13	17	14	5	49
Unclassified	0	0	0	0	0
Sex ratios: adult females/male	6.00	3.40	-	-	5.91
Age ratios: juveniles/adult female	0.36	0.33	0.38	-	0.38
juveniles/adult	0.28	0.24	0.38	-	0.30

Table 7. Area 1: age and sex classification of observed elk.

	Stratum					
	Coniferous Forest	Seral Forest	South Slopes	Ridges	Outside Sampled Plots	Totals
Adult mates	0	2	16	0	2	20
Adult females	0	7	25	0	2	34
Adult unsexed	0	0	0	0	0	0
Juveniles	0	1	8	0	0	9
Unclassified	0	0	1	0	143	144
Sex ratios: adult females/male	-	3.50	1.56	-	1.00	1.70
Age ratios: juveniles/adult female	-	0.14	0.32	-	0.00	0.26
juveniles/adult	-	0.11	0.20	-	0.00	0.17

for each species indicate fairly low juvenile:adult female ratios and the possibility of low reproductive rates and/or high mortality.

7. PREDATORS

Direct sightings of predators were limited to 2 wolves (black) on Butler Ridge, in close proximity to a small caribou herd, and one coyote on the reservoir, feeding from a deer carcass. Numerous small tracks were noted at lower elevations through the Aylard, Adams and Dunlevy creek watersheds. Forest canopy cover was too dense in many areas to permit reliable sighting of tracks or predators, or to attempt development of a predator track index.

8. POTENTIAL ENHANCEMENT AREAS

Estimates made of ungulate densities and distributions, and the impressions gained of the terrain and vegetative characteristics of the census areas, suggest the following points to consider for future habitat enhancement.

a. Moose numbers are significantly lower in steep, high- elevation and/or densely forested areas. Only the forest cover- can be practically altered by logging or burning. Prime areas for enhancement would therefore be of low to moderate elevation, have shallow to moderate slopes, and support dense forest cover.

b. Elk are restricted in distribution to sparse to moderately treed south-facing ridges overlooking Williston Reservoir. Effective habitat improvement would best be directed towards increasing the area of such biophysical types within short distances of the reservoir shoreline.

c. Logging or clear-cutting with intervening cover strips are preferred methods of habitat enhancement where merchantable timber is available and where conditions are appropriate for logging and logging access. Burning would be the next preferred approach to forest cover modification.

d. The generally low numbers of sheep in relation to the available ridge and slope habitats suggest that habitat quantity is not an important constraint per se. Habitat quality, competition or other factors are probably more important in population limitation. It would require more intensive study to determine these limitations and to decide whether sheep would respond to common habitat enhancement measures such as burning.

e. Area 1 presently supports much lower densities of moose than Area 2 and should be the priority area for habitat enhancement at this stage.

Approximately 80 km2 within Area 1 (Figure 6) meets the suggested criteria for enhancement, i.e. limitations for moose and elk caused mainly by the density of prevailing coniferous forest cover (and associated factors such as forage limitations). Large portions of these areas are old burns and are presently covered by very dense young even-aged conifer stands. These areas would best be modified through a planned burning program. In addition, 12 km2 of area appear suitable for commercial logging (Figure 6) due to prevailing mature spruce cover and relatively moderate slopes. These areas are located within the lower Dunlevy Creek drainage, adjacent to recently logged areas.

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APPENDIX A

SAMPLE PLOT DATA

Table A1. Sample plot data for ungulate census, March 1989, Area 1, north shore of Peace arm, Williston Reservoir.

Plot	Plot Area (km2)	Track Index (*1)	Snow Index (*2)	Canopy Index (*3)	Species	Adult Males	Adult Females	Unclassified Adult	Juveniles	Total
Coniferous Forest										
C 4	0.43	0		4						0
C 17	0.78	0								0
C 21	0.43	0		4						0
C 24	0.36	0		4						0
C 31	0.49	0		4						0
C 41	0.60	0		4						0
C 47	0.66	0		4						0
C 66	0.51	0		4						0
C 70	0.62	0								0
C 76	0.93	0		4						0
C 80	0.90	0		4						0
C 85	0.77	0								0
C 89	0.62	0		4						0
C101	0.54	0		4						0
C110	0.47	0		4						0
C116	0.87	0		4						0
C119	0.66	0		4						0
C140	0.82	2	4	4	Moose	1	1			2
C157	1.17	3	4	4	Moose	1	1			2
C170	0.66	0	4	4						0
C180	1.09	0		4						0
C194	0.55	0		4						0
C198	0.55	0		4						0
C200	0.90	0		4						0
C204	0.54	3	3	4	Moose		1			1
C208	0.58	0		4						0
C220	0.79	0		4						0
C230	0.84	0								0
C236	0.82	0		4						0
C237	0.80	0		4						0
C245	0.49	0		4						0
C249	0.43	0		4						0
C250	0.43	0		4						0
C306	0.20	0								0
C311	0.51	0		4						0
C312	0.63	0								0
C317	1.47	1	3	4	Moose		1		1	2
C330	0.54	0								0

Continued ----->

Table A1.' Continued.

C331	0.66	0	3	2	Moose	1	1
C332	0.79	0		3			0
C333	0.71	0		4			0
C334	0.77	0		4			0
C335	0.77	0		4			0
C336	1.07	0		4			0
C337	0.77	0		2			0
C338	0.81	1		4			0
C339	0.81	0		4			0
C340	0.63	0		3			0
C341	0.65	0		4			0
C342	0.46	0		4			0
C343	0.38	0		4			0
C344	1.12	0		3			0
C345	0.70	0		4			0
C346	0.58	0		4			0
C347	0.71	0		4			0
C348	1.14	0		4			0
C349	0.63	0		4			0
C350	0.41	0		4			0
C351	0.85	0		4			0
C352	0.63	1		4			0
C353	0.82	0					0
C354	1.25	1		3			0
C355	0.17	0		4			0
C356	0.82	0		3			0
C357	0.57	0		2			0
C358	1.00	0					0
C359	0.35	0		2			0
C360	0.71	0		4			0

plots = 60
Mean size = 0.70 ka2
Minimum size = 0.17 ka2
Maximum size = 1.47 ka2

Seral Forest

D 7	0.35	0		4			0
D 8	0.27	0		3			0
D 10	0.77	0					0
D 11	0.54	0		4			0
D 15	1.00	0		3			0
D 24	0.28	0					0

Continued ---->

Table A1. Continued.

D 25	0.49	0		3							0
D 29	0.54	0		3							0
D 37	0.70	0		3							0
D 40	0.35	0		4							0
D 41	0.82	0		4							0
D 50	0.77	0		4							0
D 53	0.73	0									0
D 60	0.47	0		4							0
D 64	0.65	0		4							0
D 67	0.79	0		3							0
D 70	0.81	0		4							0
D 71	0.88	0		3							0
D 72	0.87	0		3							0
D 74	0.82	1		2							0
D 75	1.23	1		2							0
D 76	1.00	0		3							0
D 80	0.55	1		4							0
D 81	0.66	1	4	3	Moose		3				3
D 82	0.62	1	4	3	Moose	1	1	1			3
D 84	0.49	0		3	Moose	1	1				2
D 86	0.93	1		3							0
D 89	0.62	0		4							0
D 96	1.01	0		4							0
D102	0.44	0		2							0
D112	0.60	0		4							0
D113	1.12	1	4	4	Moose	1					1
D115	0.70	0		4							0
D117	0.44	0		3							0
D119	0.65	1	3	3	Moose	2					2
D121	1.11	0		3							0
D123	0.68	0		3							0
D124	0.51	1	2	3	Moose		2				2
D127	0.93	0		3							0
D130	1.25	1		3							0
D133	0.71	2		3							0
D134	0.98	3	3	4	Moose		1			1	2
D141	0.79	0		3							0
D144	0.62	1	2	3	Moose			1			1
D147	0.76	1	3	2	Moose			1			1
D153	1.19	0		3							0
D154	0.87	0		3							0
D156	1.06	0		4							0
D158	0.79	0		3							0
D159	0.74	1		4							0
D162	0.98	0		4							0
D165	0.74	2		4							0
D167	0.77	0		4							0

Continued ------>

Table A1. Continued.

D168	1.38	1	3	4	Elk	1	2		1	4
					Moose		1	1		4
					MD					4
D171	0.47	3	3	3	Moose	2	1	1		4
D172	0.87	0		3						0
D176	0.90	2	2	2	WT					3
					Elk	1				1
					Moose		2			2
D178	0.84	0		3						0
D180	0.70	1	2	2	Moose	1				1
D183	1.74	1		3						0
D187	0.93	0		3						0
D204	1.09	3	3	2	Moose		6		1	7
D205	0.95	1		4						0
D206	0.74	2								0
D207	1.15	4	2	4	MD					4
					Moose	4	3		1	8
					Sheep		4			4
D208	0.28	0		3						0
D209	0.70	3	2	3	Elk		5			5
D210	0.58	1		4						0
D212	0.66	1	3	3	Moose		2			2
D213	0.60	0		3						0
D214	1.12	2	3	3	Moose		2			2
D215	1.09	1	3	3	Moose		3		3	6

0 plots = 72
Mean size = 0.78 km2
Minimum size = 0.27 km2
Maximum size = 1.74 km2

Ridges

R 1	0.49	0		0						0
R 3	0.30	0		0						0
R 4	0.58	0		0						0
R 5	0.41			2						0
R 7	0.47	0		0						0
R 8	0.36			1						0
R 12	0.35	1	2	0	Sheep	2				2
R 14	0.32			1						0
R 15	1.20			0						0
R 16	0.41			0						0
R 20	0.45			0						0

Continued ---->

Table A1. Continued.

R 21	0.25			0					0
R 22	0.28			0					0
R 23	0.30	0	1	0	Sheep		3		3
R 24	0.27			0					0
R 25	0.28		1	0	Caribou		8	9	3	20
R 26	0.22	0		2					0
R 30	0.49		1	0	Caribou	1	4	8	2	15
R 31	0.35	0		2					0
R 32	0.32			2					0
R 40	0.51			0					0
R 41	0.33	4	1	0	Caribou					4
R 43	0.60		2	0	Caribou	3				3
R 47	0.41	1	1	0	Caribou					7
					Sheep	1	2			3
R 49	0.60	0		0						0
R 52	0.35			0						0
R 54	0.60		1	0	Sheep	2				2
R 55	0.35	0		0						0
R 56	0.77	1	1	0	Caribou			17		17
R 58	0.57	1	1	0	Sheep	1	7		4	12
R 59	0.77	1		0						0
R 61	0.40	0		1						0
R 63	0.47			1						0
R 67	0.65			4						0
R 68	0.60	3		0						0
R 71	0.44	0		2						0
R 74	0.49	0		0						0
R 78	0.25			1						0
R 81	0.24	0		3						0

0 plots = 39
Mean size = 0.45 km2
Minimum size = 0.22 km2
Maximum size = 1.20 km2

South Slopes

S 2	0.49	0		4					0
S 3	0.24	0		4					0
S 4	0.92	0		4					0
S 5	0.25	0		4					0
S 8	0.81	0		4					0
S 9	0.38	0		4					0
S 10	0.13	0		3					0

Continued ------>

Table A1. Continued.

S 15	0.85	1	3	2	Moose		1		1
S 16	0.70	0		2					0
S 17	0.40	1		3					0
S 19	1.07	0		3					0
S 20	0.41	0		4					0
S 21	0.92	0		4					0
S 22	0.70	0		4					0
S 23	0.13	0		1					0
S 24	0.90	0		4					0
S 27	0.70	1	3	2	Moose		1		1
S 30	0.54	0		2					0
S 34	0.44	0		3					0
S 35	0.24	0		3					0
S 37	0.66	0		3					0
S 38	0.74	0	2	2	Caribou		1	1	2
S 40	0.74	1	4	3	Moose		1		1
S 41	0.54	0		4					0
S 42	0.63	0		4					0
S 43	1.01	0		2					0
S 44	0.76	3	3	3	Moose		5	4	9
S 46	0.71	3	3	3	Elk	1			1
					Moose	3			3
S 47	0.46	0	3	2	Caribou		1	1	2
S 48	0.49	0		0					0
S 50	0.93	0		2					0
S 51	0.11	0		3					0
S 53	0.27	0		2					0
S 55	0.32	1		3					0
S 56	0.63	0		3					0
S 58	0.62	0		3					0
S 60	0.22	0		4					0
S 65	0.19	0		2					0
S 66	0.71	1		2					0
S 67	0.96	4	2	2	W/T deer				4
					Elk	10	9		19
					Moose		1		1
S 68	0.55	4	2	2	Moose		2	1	3
S 72	0.51	0	4	4	Mule deer			1	1
S 73	0.57	0							0
S 76	1.14	0		2					0
S 78	0.82	3	2	2	Moose		1		1
S 79	1.06	3	4	3	Moose	2	5	2	9
S 80	0.51	0		2					0
S 81	1.28	0		2					0
S 82	1.11	3	4	3	Moose	2	7	4	13
S 83	0.68	2			Moose	1	1	1	3
S 84	0.85	0		4					0

Continued ---->

Table A1. Continued.

S 85	1.03	0		4					0
S 86	0.82	0		4					0
S 87	1.09	0							0
S 88	1.28	0							0
S 90	0.48	3	2	2 Moose			1		1
S 91	0.95	4	2	2 Moose		1		1	2
S 92	1.22	2	2	3 Moose	1	3			4
S 93	0.96	3	2	2 Moose	4	5		2	11
S 95	0.57	3	2	2 Moose	2	6		3	11
				Elk	5	16		8	29
				Mule deer					2
S 96	0.54	3	2	3 Moose	1	3			4
				Mule deer					7
				Elk					1
S 97	0.52	1	3	3 Moose	1				1
S 98	0.85	0		2					0

0 plots = 63
Mean size = 0.67 km2
Minimum size = 0.11 km2
Maximum size = 1.28 km2

#1 Track index: 0 - none
1 - single
2 - sparse
3 - abundant
4 - very abundant

#2 Snow index: 1 - coverage < 100%
2 - " > 100%, shallow
3 - " " , < moose chest height
4 - " " , > moose chest height

#3 Canopy index: 0 - no tree canopy
1 - open, sparse tree cover
2 - wooded, good visibility
3 - wooded, moderately dense canopy
4 - wooded, dense canopy

Table A 2. Sample plot data for ungulate census, March 1989, Area 2, north shore of Peace arm, Williston Reservoir.

Plot	Plot Area (km2)	Track Index (#1)	Snow Index (#2)	Canopy Index (#3)	Species	Adult Males	Adult Females	Unclassified Adult	Juveniles	Total
Agricultural Lands										
A 1	0.35	4	3	0	Moose		5		3	8
A 2	0.55	3	3	0	Moose		1		1	2
A 3	0.68	0	3	1						0
A 5	1.34	3	3	1	Moose		2			2
A 17	1.34	3	3	1	Moose		8		3	11
A 23	1.05									0
A 10	1.14	0	3	1						0
A 13	1.58	0	3	1	Moose		1		1	2
A 14	1.91	0	3	0	Moose		1		1	2
A 18	0.58	0	3	1	Mule deer					19
					Moose		9		1	10
A 24	0.60	0	3	1						0
A 27	1.19	0	3	1						0
A 28	1.30	0	3	1	Moose		7		1	7
A 29	0.99	0		1						0
A 31	1.42	1	3	1	Moose		1		1	2
A 34	0.74	0	3	0						
A 35	0.86									
A 37	0.82	2	3	2	Moose		2		2	4
					Mule deer					2

0 plots = 18
Mean size = 1.02 km2
Minimum size = 0.35 km2
Maximum size = 1.91 km2

Coniferous Forest										
C 3	0.77	1	3	4						0
C 7	0.55	2	3	4	Moose	1	1			3
C 9	0.77	4	3	4	Moose	1	6		2	9
C 10	1.03	2	3	4	Moose	1	1	1		3
C 11	0.52	4	3	4	Moose	1	10	1	5	17

Continued ------>

Table A2 Continued.

C 16	1.12	2	3	3	Moose	1				1
C 22	1.60	0	3	3						0
C 33	2.38	0		4						0
C 35	2.48	3	3	4	Moose		5		3	8
					Mule deer			4		4
C 42	0.55	3	3	3	Moose	1	7			8
C 45	1.04	3	3	4	Moose		1		1	2
C 50	0.76	0	3	3						0
C 51	0.79	1	3	3						0
C 56	0.52	1	3	4	Moose		1			1
C 69	0.62	2	3	4						1
C 92	1.37	0	3	4	Moose		1		1	2
C 94	0.76	1	3	4						0
C 94	0.76	2	3	4	Moose			1		1
C 95	0.96	0	3	4						0
C 96	0.77	1	3	4						0
C 98	0.73	0	3	4						0
C101	1.39	0	3	4						0
C101	1.39	1	3	4	Moose		1			1
C103	0.58	1	3	4						0
C103	0.58	0	3	4						0
C104	0.84	1	3	4	Moose		2		1	3
C105	1.25	0	3	4	W/T deer					6
C106	1.47	1	3	4						0
C107	1.42	1	3	4	Moose			1		1
C108	1.04	0	3	3						0

0 plots = 38
Mean size = 1.03 km2
Minimum size = 0.52 km2
Maximum size = 2.48 km2

Seral Forest

D 3	0.60	3	3	2						0
D 4	0.35	3	3	2	Moose			3		3
D 6	0.62	2	3	3	Moose	1	1			2
D 7	1.01	4	3	3	Moose	1	5		3	9
D 15	0.74	2	3	4						0
D 17	0.49	1	3	3	Moose		1			1
D 19	0.63	2	3	3	Moose		3			3
D 30	0.95	1		3						0
D 31	1.50	1		3						0
D 33	1.07	3	3	4	Moose	1	4			5

Continued ------>

Table A2. Continued.

D 42	1.42	3	3	2	Moose		5		1	6
D 46	0.81	3	3	4	Moose		1		1	2
D 47	0.36	2	3	4	Moose		2		2	4
D 51	1.03	0	3	4						
D 52	1.14	2	3	4	Moose		2			2
D 53	0.92	0	3	4	Mule deer					4
					Moose		1			1
D 57	0.71	0	3	3						
D 60	0.66	1	3	3	Moose	1	1			2
D 61	1.06	2	3	4						0
D 62	0.82	1	3	4	Moose		2		1	3
D 64	0.96	2	3	3	Moose		3		2	5
D 67	1.44	2	3	2	Moose		1			1
D 71	1.41	3	3	2	Moose		1		1	2
D 79	0.60	0	3	3						
D 80	0.63	2	3	2						0
D 82	0.98	2	3	2						0
D 85	1.41	1	3	0						0
D 86	1.26	1	3	0	Moose	0	2		2	12
					W/T deer			2		2
D 87	0.65	0	3	1	Moose	2				2
D 88	0.58	2	3	1						0
D 89	0.58	0	3	1						0
D 90	0.36	0	3	1						0
D 91	0.62	3	3	0	Moose		2		1	3
D 92	1.52	1	3	2	Moose		1	1	1	3
D 93	1.15	1	3	2	Moose		2		1	3
D 94	1.09	2	3	3	Moose		1			1
D 95	1.52	2	3	2	Moose		2			2
D 96	1.19	1	3	4	Moose		1			1
D 97	1.15	1	3	2						0
D 98	1.00	3	3	3	Moose	1	2		1	4
D 99	0.52	1	3	4	Moose		1	1		2
D100	0.73	3	3	3	Moose		1			1
D101	0.81	0	3	4	Moose		1			1
D102	0.96	2	3	4						0
D189	0.93	2	3	3	Moose		1			1
D197	1.19	0	3	3						0
D200	0.79	4	3	3	Moose		1			1

0 plots = 47
Mean size = 0.91 km2
Minimum size = 0.35 km2
Maximum size = 1.52 km2

Continued ------>

Table A2. Continued.

#1 Track index:	0 - none
	1 - single
	2 - sparse
	3 - abundant
	4 - very abundant
#2 Snow index:	1 - coverage < 100%
	2 - " > 100%, shallow
	3 - " " , < moose chest height
	4 - " " , > moose chest height
#3 Canopy index:	0 - no tree canopy
	1 - open, sparse tree cover
	2 - wooded, good visibility
	3 - wooded, moderately dense canopy
	4 - wooded, dense canopy

APPENDIX B

STATISTICAL ANALYSES

B.1 VISIBILITY CORRECTIONS FOR CENSUSED UNGULATES

Two methods were used in the census to derive correction factors for the visibility (or "sightability") of ungulates in forested habitats. These factors were derived for moose only since a relatively large proportion of these animals occurred in dense canopy forest where visibility was markedly impaired. The other species included in the census - elk, sheep and caribou - occurred predominantly along open ridges and slopes where observer efficiency was not hampered by tree cover.

A number of sample plots in both areas 1 and 2 were censused twice, i.e. a plot was recounted immediately after an initial survey. The concept was recommended by Gasaway et al. (1986) in censusing moose in boreal forest in Alaska and rests on the assumption that a plot can be surveyed intensively enough to ensure almost 100 percent efficiency in detection of moose and the computation of a reliable correction factor ([intensive count - regular count]/regular count) for use on all sampling plots.

The decision to sample a particular plot twice was taken in the field when the initial survey of a plot had been completed and was based on two factors:

a. the occurrence of a relatively high density of moose in the plot;

b. a zero count in a plot with a high track index, suggesting that moose were present in the plot but had been missed by the observers.

The proposed survey plan allowed for about 20 percent of plots to be resampled. Following the completion of 15 such sample plots (Table B.I), it became apparent that the second or "intensive" count could not be relied upon to be 100 percent efficient, and the procedure was curtailed. The following were noted:

a. complete efficiency of counts in very dense canopied forest would have required very slow helicopter speeds (- 20 knots) and long search times, with serious implications for the overall amount of helicopter time required for the census.

b. different strata had different visibility conditions (mainly due to differences in tree canopy cover) and therefore each stratum required

its own correction factor, again with serious implications for flying time required;

c. there was no guarantee that the observers were any more efficient during the intensive count than in the regular counts and, more importantly, the efficiency could not be quantitatively estimated. Repeat censuses of 15 plots (Table B.1) resulted in a mean increase of 8.5 percent in numbers of moose seen per plot (or 10.9 percent if the one plot with a lower second count is discounted).

The second approach to correcting for observer efficiency in sighting moose was to adjust the counts per sample plot according to three groups of factors:

a. those which could negatively affect observer efficiency, e.g. canopy density;

b. those which could be used as indices of moose abundance, i.e. track abundance;

c. those which could be correlated with general moose abundance, e.g. size of the plot, stratum type, etc.

The advantage of this approach is that the counts could be adjusted according to the conditions prevailing within each particular plot and within separate strata.

The quantitative relationship of these factors to moose numbers per plot was examined by the use of stepwise multiple regression. Qualitative indices such as track abundance and canopy density were converted to categorical variables (1 for present, 0 for absent). Plot size was entered as a simple quantitative variable. The coefficient of determination between moose numbers and these factors alone and in various combinations was examined. Separate analyses were undertaken for Areas 1 and 2. Corrections were not attempted for species other than moose, since no reliable track index was available for these species and they occurred predominantly in open terrain.

The snow depth index was found to have no significant relationship to moose numbers per plot in either census area. Canopy cover slightly affected moose numbers per plot in Area 1 but not in Area 2, where cover

Table B.1. Williston ungulate census: areas 1 and 2: repeat counts of moose.

Stratum	No. Moose Observed: First Sample	Second Sample	Difference	Plot Area (km2)	Track Index	Snow Cover	Canopy Cover
Coniferous forest	0	1	1	0.54	Abundant	Deep	Mod. dense
	2	2	0	1.47	Single	Deep	Mod. dense
	0	0	0	0.81	Single	Deep	Dense
Seral forest	1	1	0	1.12	Single	Deep	Dense
	1	1	0	0.76	Single	Shallow	Mod. dense
	2	2	0	0.90	Sparse	Mod. deep	Mod. dense
	1	1	0	0.70	Single	Shallow	Sparse
	8	8	0	1.15	Very abundant	Deep	Sparse
	1	2	1	0.66	Single	Mod. deep	Mod. dense
	2	2	0	0.49	Single	Mod. deep	Dense
South slopes	9	9	0	1.06	Abundant	Mod. deep	Dense
	4	5	1	1.28	Abundant	Shallow	Sparse
	4	6	2	1.11	Abundant	Mod. deep	Dense
	1	0	-1	0.40	Abundant	Shallow	Sparse
	11	11	0	0.96	Abundant	Mod. deep	Sparse

type indices were found to have a stronger effect on moose numbers per plot (large proportion of moose in open fields with excellent visibility-). Plot size had no effect on moose numbers in either census area. A relatively low significance level (p 0.1) was used in selecting variables to use in adjustment of moose numbers per plot . Multiple regression equations based on the selected variables (Table B.2) were used to predict the expected number of moose in each plot on the basis of the prevalent track index and a presumed zero canopy cover (in Area 1) or zero tree cover (in Area 2). These predicted numbers were compared to the actual numbers seen. When predicted numbers exceeded the observed numbers the former were chosen; observed numbers were selected in all other cases.

Overall adjustments to moose numbers per plot ranged from a low of 3.9 percent for agricultural lands in Area 2 to a high of 87.5 percent for coniferous forest in Area 1. The mean adjustment percentage for Area 2, where higher densities of moose were seen, was 12.6, which compares closely with sightability correction factors used in aerial censusing in similar forest cover type elsewhere (e.g. 12.4 percent used by Gasaway et al. (1986) in Alaska based on known numbers from radio-telemetric observations). The high adjustment factors for coniferous and serai forest in Area 1 reflect in part the very dense canopies in those strata, but are probably also the result of relatively small sample sizes. This may have resulted in a over-correction for moose numbers per plot in these two strata.

B.2 STATISTICAL DISTRIBUTION OF SAMPLE DATA

The main purpose in fitting sample data to a statistical distribution is to obtain a probability density function and thereby to estimate the confidence limits for specific parameters such as the mean. As noted below, there are secondary values in estimating the parameters of such distribution functions, i.e. some of the parameters may have ecological significance. The estimate of the mean (mean density or mean no. ungulates per plot) is generally the same for most common statistical distributions.

B.2.1 Quadrant Data

Because of its relative efficiency and widespread use, the normal distribution is preferred to other distributions for most statistical

Table B.2. Williston ungulate census: areas 1 and 2: multiple regression of moose numbers observed per sample plot on various condition indices.

Area 1:

Variable	Regression Coefficient	t Value	P
Constant	-0.31	-1.04	0.302
Track Index 1	0.87	3.31	0.001
Track Index 2	1.41	2.91	0.004
Track Index 3	5.09	14.05	0.000
Track Index 4	3.54	5.18	0.000
Canopy Index 1	0.31	0.51	0.612
Canopy Index 2	0.29	0.75	0.456
Canopy Index 3	0.72	2.06	0.041
Canopy Index 4	0.22	0.67	0.504

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Model	431.64	8	53.96	31.22	<0.001
Error	368.07	213	1.73		
Total	799.71	221			

R2 = 0.54

Area 2:

Variable	Regression Coefficient	t Value	P
Constant	1.88	2.67	0.009
Track Index 1	1.11	1.38	0.172
Track Index 2	1.14	1.4	0.164
Track Index 3	3.23	3.75	0.000
Track Index 4	8.03	6.26	0.000
Stratum Index 1	-1.22	-1.41	0.163
Stratum Index 2	-1.55	-1.89	0.062

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	P
Model	339.28	6	56.55	8.24	<0.001
Error	562.76	82	6.86		
Total	799.71	88			

R2 = 0.38

analyses. However, the ungulate plot sampling data obtained in this census were found not to fit a normal distribution, either in their raw form (no. ungulates per plot, no. ungulates per km2 per plot) or in a transformed form (logarithmic, square root, arc sin, etc.). The major reason for the lack of fit is the large number of zero count plots. This results from the relatively small size of the sample plots relative to the overall density of ungulates in the census areas. The mean size of sample plots in Area 1 was 0.68 km2 and 0.97 km2 in Area 2 . Plot size was determined primarily on the basis of sampling efficiency in the highly dissected terrain of Area 1 and was not specifically intended to suit any particular statistical distribution. The smaller the sample plot the more efficient it is to locate their boundaries in the field and to search them thoroughly.

To overcome this lack of normality in the sampling data, the basic sampling unit used was a quadrant, which was a 25 km^2 area based on a 5 x 5 km block encompassing 25 UTM 1 km squares as defined on the 1:50,000 NTS map series. Sampling plots falling within each quadrant as outlined on the aerial photographs were regarded as sub-samples of the respective quadrants, regardless of the stratum type. Estimates of mean ungulate densities throughout Areas 1 and 2 were the same whether calculated from quadrant data or from plot data, but distribution of moose per quadrant was approximately normal for both Areas 1 and 2 and were thus used for computation of 90 percent confidence limits. Quadrant data were not normally distributed for the other species, despite the relatively large size of the quadrants, and confidence limits for elk, sheep and caribou were based on the Poisson distribution (see below).

B.2.2 Plot Data

Several other distributions were examined for fitting sample plot data, including the Poisson, binomial, negative binomial and geometric. Of these, the Poisson distribution appeared to be the most promising. The Poisson distribution describes the distribution of the numbers of randomly distributed discrete objects within a series of sample plots, and has the form

$$P_x = \frac{\lambda e^{-\lambda}}{X!}$$

where P_x - probability that a sample plot will contain X individuals

λ = mean number of individuals per plot

X = 0,1,2,3,4

e = base of natural logarithms

The variance of a Poisson distribution is equal to the mean λ.

Close statistical fits of the sample data to the standard Poisson distribution were hampered by the peculiar distribution of ungulates within the sample plot series, i.e. large numbers of zero count plots and a small number of plots covering a wide range in numbers. This suggested the possibility of some heterogeneity within the sample plots within the strata which was influencing ungulate distribution.

Pielou (1969) notes that sample units may be heterogeneous but this may not be apparent to an observer (conducting a census). In such cases the randomly selected sample plots may be of two types - those with an average probability of being occupied on the basis of random distribution of the population, and those with a low probability of being occupied because they are not "habitable" (Pielou's terminology). In such cases, the sample data may fit a modified Poisson distribution of the form

$$P_x = \frac{\theta \lambda e^{-\lambda}}{X!}$$

where P_x, λ and e are as defined above, and θ is the proportion of habitable sampling units. The probability P_0 of an unoccupied plot is given by

$$p_0 = 1 - \theta + \theta e^{-\lambda}$$

and the mean of the series is estimated by the product $\theta \lambda$.

The sample data for each ungulate species were found to fit the modified Poisson distribution in all cases. The Kolmogorov-Smirnov test (Zar 1984) was used to determine goodness of fit since it permits the inclusion of small numbers (<5) whereas the chi-square test does not. The initial estimate of θ, the proportion of habitable sample units, for each ungulate species for each census area, was given by

$$\theta = \frac{\text{No. of non-zero sample units}}{\text{Total no. units sampled}}$$

In most cases, this estimate proved to be adequate; a few data series required adjustment of this parameter to enable a close fit to the modified Poisson distribution.

Confidence limits for the mean of a Poisson distribution were estimated (Zar 1984) as

$$L_l = \frac{X^2(1-\alpha/2,v)}{2} \quad \text{with } v = 2\lambda$$

$$L_u = \frac{X^2(\alpha/2,v)}{2} \quad \text{with } v = 2(\lambda+1)$$

where L_l = lower confidence limit
L_u = upper confidence limit
λ = mean value of Poisson series
α = desired one-tailed probability level = 0.1 (10 percent)
X^2 = tabular chi-square value

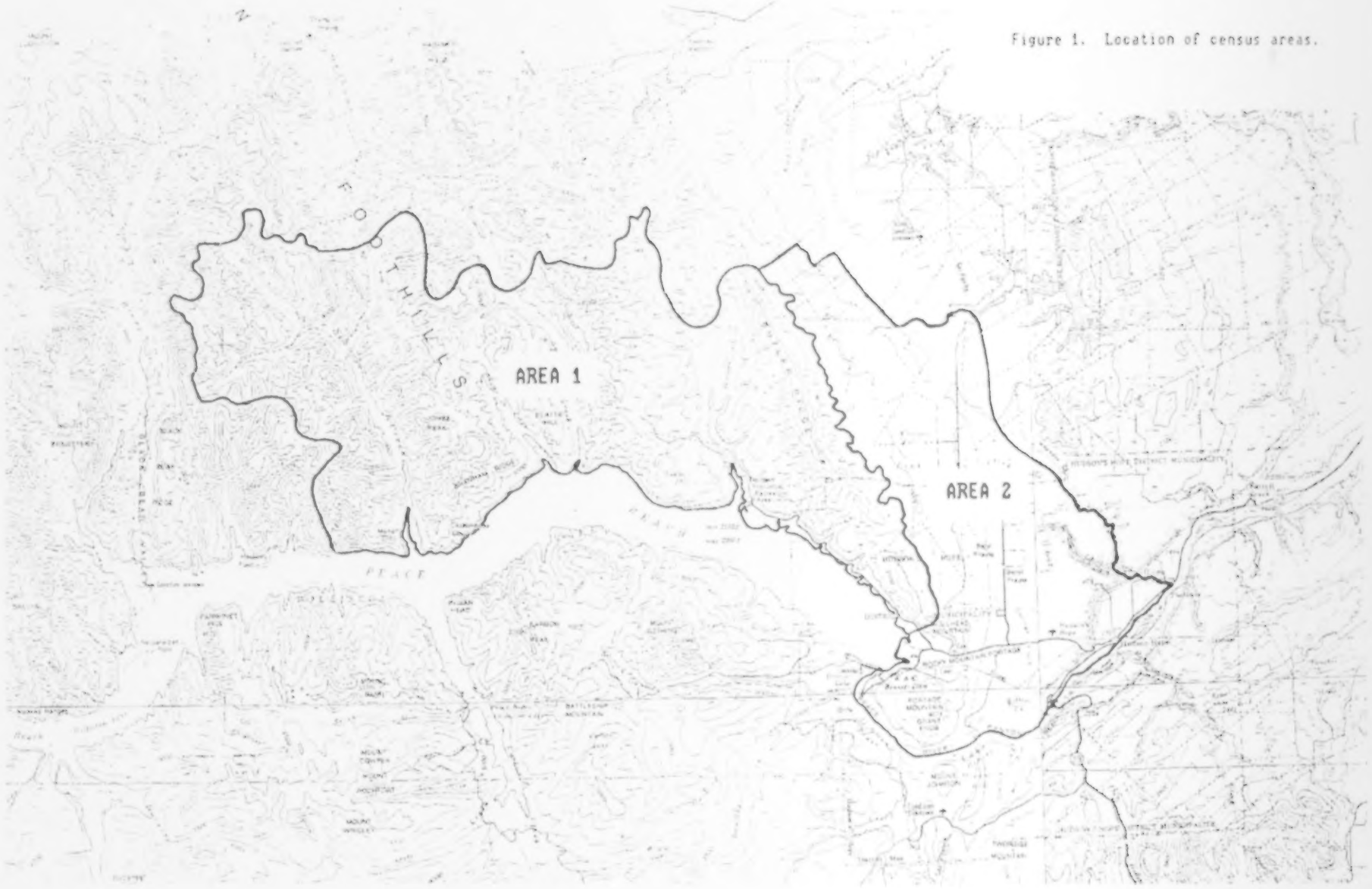
Apart from their use in estimating densities and total population sizes, the parameters λ and θ provide some useful quantitative insights into ungulate distribution within the census areas. The proportion of habitable units θ differs significantly between strata and between species, suggesting underlying ecological differences and habitat limitations. Especially noticeable is the significant difference in the proportion of habitable units for moose in coniferous forest in areas 1 and 2 (chi square = 18.8, $p<0.001$), indicating that Area 1 has some significant constraints, possibly slope and elevation. θ for moose does not differ significantly between strata in Area 2 (chi square = 2.26, df = 2, $0.5>p>0.25$); λ for moose in Area 2 does not differ significantly between strata either (Z test, Zar 1984), suggesting a similarity of winter habitats for moose throughout this census block.

Table B.3. Williston ungulate census: areas 1 and 2: parameters for fitting ungulate census data to modified Poisson distributions.

Area	Species	Stratum	Proportion of Habitable Units (O)	Mean No. Ungulates per Occupied Plot (\)	Mean No. Ungulates per Sample Plot (O\)	Lower Confidence Limit (LL)	Upper Confidence Limit (UL)
1	Moose	Coniferous forest	0.15	1.59	0.24	0.18	5.54
		Seral forest	0.61	1.57	0.96	0.18	5.54
		South slopes	0.32	4.38	1.40	1.66	9.84
		Ridges	–	–	–	–	–
1	Elk	Coniferous forest	–	–	–	–	–
		Seral forest	0.05	2.78	0.14	0.57	7.75
		South slopes	0.06	13.23	0.79	7.69	20.67
		Ridges	–	–	–	–	–
1	Sheep	Coniferous forest	–	–	–	–	
		Seral forest	0.01	5.63	0.06	2.29	11.18
		South slopes	–	–	–	–	
		Ridges	0.14	4.14	0.50	1.37	9.15
1	Caribou	Coniferous forest	–	–	–	–	–
		Seral forest	–	–	–	–	
		South slopes	0.05	0.86	0.04	0.05	4.74
		Ridges	0.16	10.86	1.74	5.80	18.21
2	Moose	Coniferous forest	0.59	3.57	2.11	1.08	8.46
		Seral forest	0.75	3.02	2.27	0.82	7.75
		Agricultural lands	0.63	5.30	3.34	1.97	10.51

The major drawback to the use of a Poisson distribution is the wide confidence limits to the mean. For the results obtained in this census the ratios between the mean and the confidence limits ranged from 3 to 10, making them of questionable practical value. Confidence limits in a Poisson distribution are not affected by the sample size as they are in the normal distribution, hence grouping strata of similar mean values (as in Area 2) produces no advantage in reducing the width of the confidence interval.

Figure 1. Location of census areas.



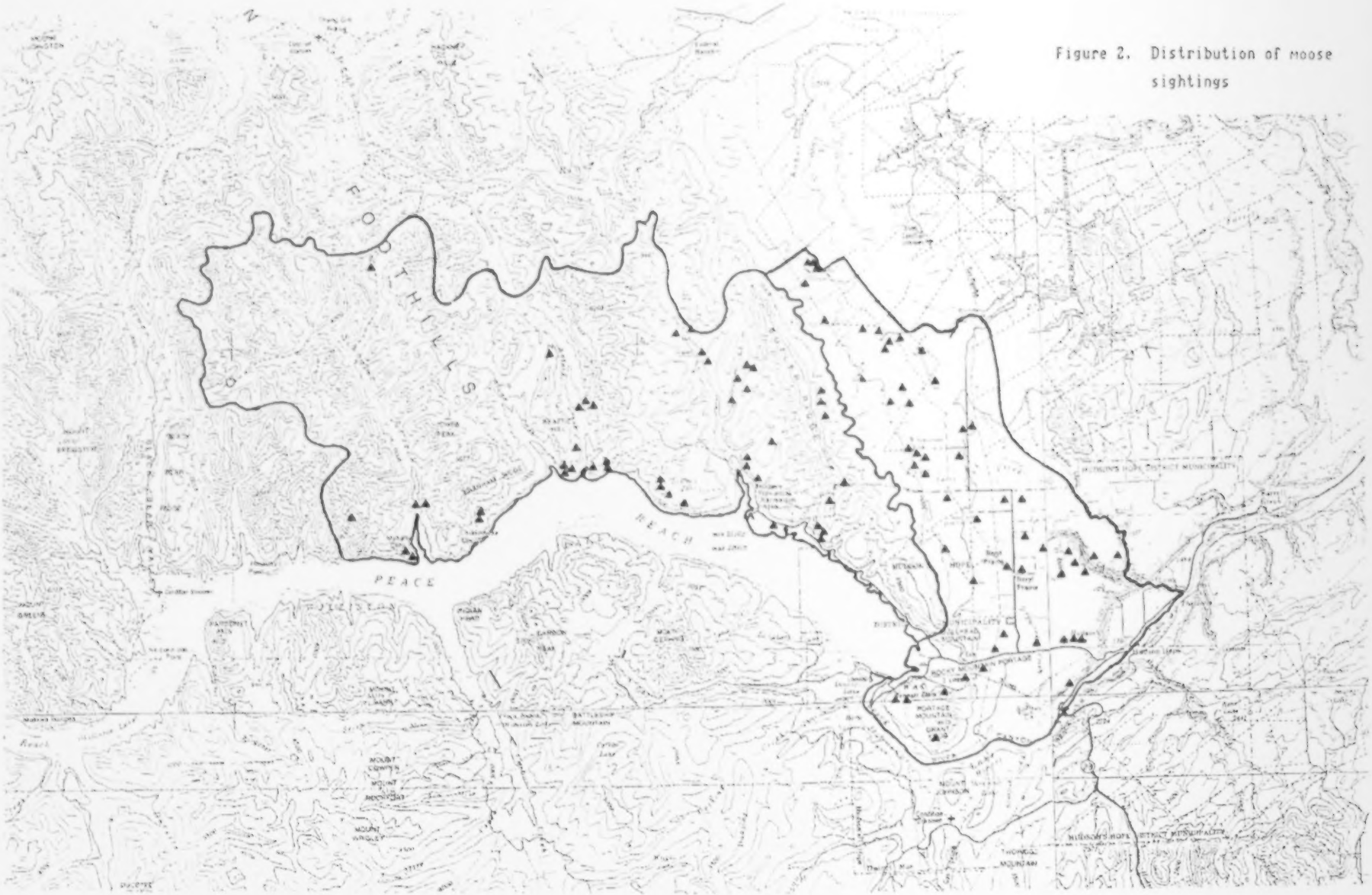


Figure 2. Distribution of moose sightings

Figure 3. Distribution of elk sightings

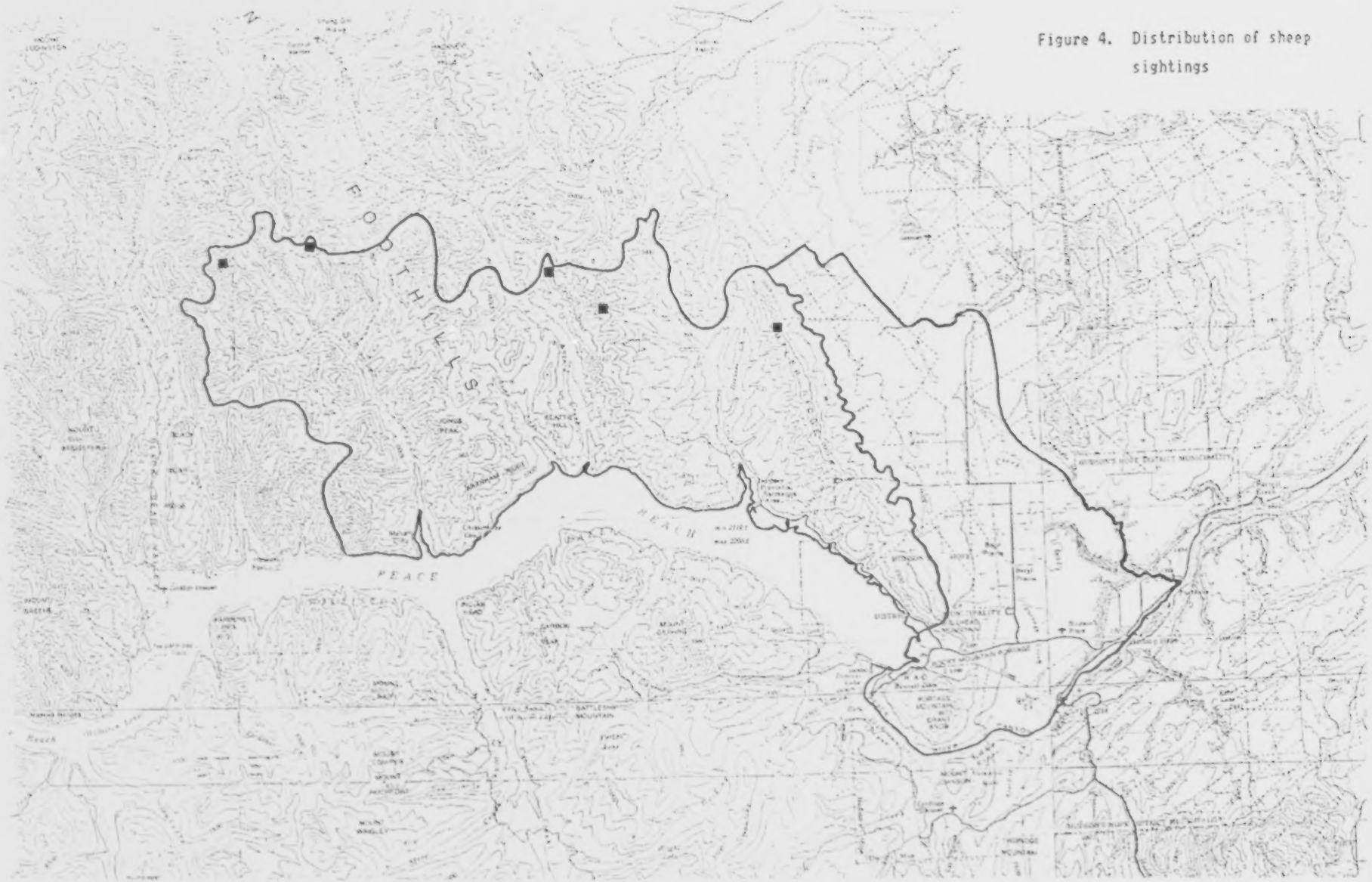


Figure 4. Distribution of sheep sightings

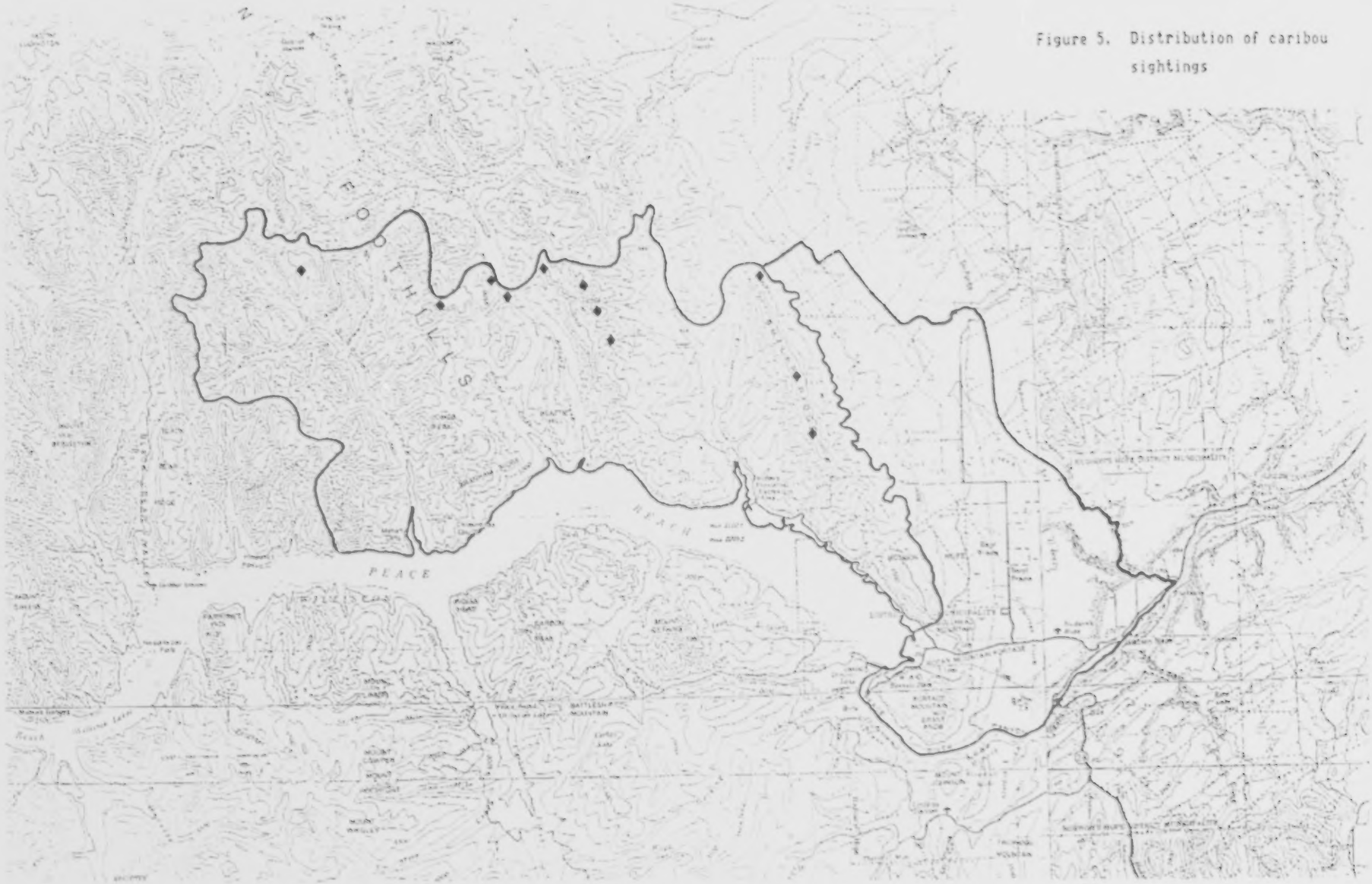


Figure 5. Distribution of caribou sightings

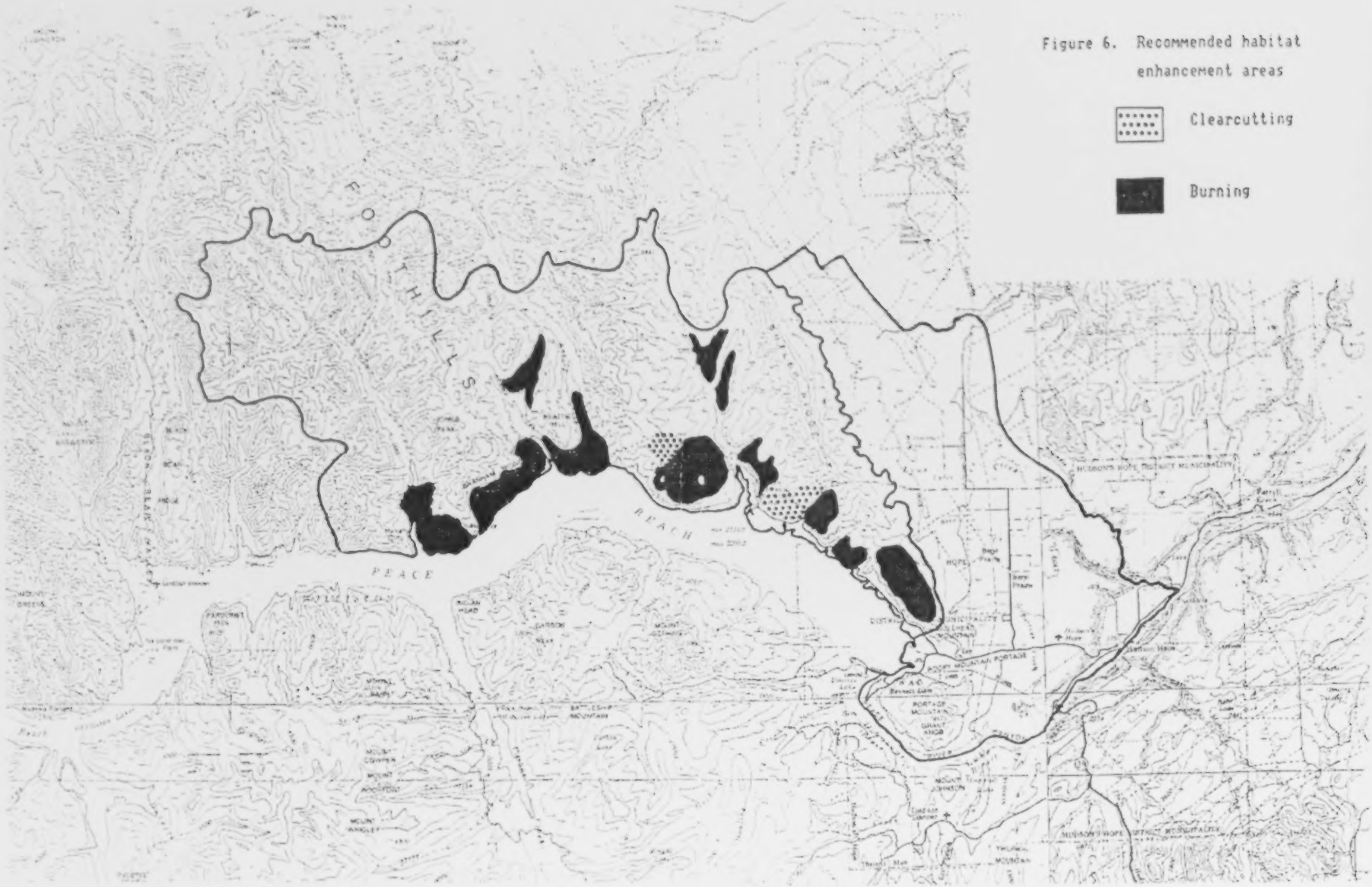


Figure 6. Recommended habitat enhancement areas